Design Research Approach in Developing Technology-Mediated Learning Modules in Practical Mathematics for Technical Vocational Education

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Abstract

Technical vocational education has become one of the four major tracks in the K to 12 curriculum in the Philippines (Ocampo, 2014). However, online learning technologies are not yet fully integrated into the core technical-vocational courses of this curriculum. Using the design research model of Mckenney and Reeves (2013) with two iterations, this study developed a set of technology-mediated learning modules in practical mathematics for the technical-vocational track of the K to 12 curriculum. From three researcher-made instruments, data were gathered from randomly selected samples from a private sectarian college. Results indicate that the design research modules were characterized by the following design principles: a) small-group collaborative learning through synchronous and asynchronous discussions based on simplified authentic problem-based tasks; b) online teaching roles as a facilitator, feedback giver, learning community mentor, course designer, and manager; c) use of Facebook and its online group chat; d) use of multimedia approach, behavioral objectives, simple language, and exercises in the presentation of the modules; and e) student context based on job skills specialization, motivation and interest in practical mathematics, familiarity with information and communication technology, and socio-economic status. Using the Mann-Whitney test at 0.05 significance level, the overall mean score of the second iteration group is significantly higher than the overall mean score of the first iteration group. This indicates that the technology-mediated learning modules facilitated the learning of practical mathematics concepts. This study recommends the design research approach because its iteration process has validated and put together effective design principles for online teaching and learning of practical mathematics. Further, it has involved both students and the teacher in developing these modules that yielded better student learning outcomes.

Keywords: *design research, practical mathematics, technology-mediated learning modules, design principles*

Introduction

Countries like Australia, Canada, and China as well as the European Community, have used online learning as the latest or dominant mode of delivery for the instruction for learners of vocational education (China Online Education Report, 2014; Stevens, 2001). In the Philippines, several short-term courses were offered by the Technical Education and Skills Development Authority (TESDA) through online learning technology. However, online learning technologies are not yet fully integrated into technical vocational education, currently a major track of the K to 12 curriculum (Ocampo, 2014). Such integration to a technical vocational course like practical mathematics may yield an online learning environment of convenience, instructor availability, and student engagement, especially to students who are time bound – due to work or distance – or place bound – due to far location or physical limitations (Juan et al., 2011).

An ongoing large body of literature shows that the online learning format is an effective way of building the learning engagement of students (Lewis & Allen 2005; McConnell, 2006). Moreover,

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this distant mode of learning yields prospects for promoting a reflective and collaborative learning environment (Koh & Hill, 2009; Land & Dornisch, 2001). From the instructors' point of view, they found online teaching advantageous because they can: a) plan their courses ahead of time; b) maintain personal communications with their students; c) have access to a variety of students; d) gain opportunity to improve their pedagogical skills; and e) have more control over the learning environment (Telmesani, 2010).

The sustained effort for a technology-based mathematics curriculum has mediated online learning of mathematics. Such technology has provided tools that make online learning more convenient, effective, and engaging.

The computing technology – like the scientific and graphing calculators and computer programs with varied mathematical functions – has freed up learners from the mechanical task of calculating and allowed them to discern and explore mathematics (Heid, 1988). The multimedia presentation of mathematical knowledge through digital boards and the Internet has fostered greater student engagement and connected mathematics abstractions to the real world (diSessa, 2001).

To develop these technology-mediated learning modules, this study used design research as an approach that is characterized as interventionist, iterative, process-oriented, utility-oriented, and theory-oriented (Kelly, 2003). This approach offers a twofold yield: a research-based intervention and a generation or validation of theories (Plomp & Nieveen, 2013). The first yield is a research-based intervention to solve a complex problem in educational practice. The second yield is a set of validated design strategies to strengthen educational learning practices in learning and teaching practical mathematics in an online environment. Also, this set of validated design strategies may add to the body of knowledge of developing technology-mediated learning modules in the mathematics curriculum of technical vocational schools.

Objectives of the Study

The study aimed to develop technology-mediated learning modules in practical mathematics for the technical-vocational track of the K to 12 curriculum following the design research approach. To address this, the study—

1. identified the characteristics of technology-mediated learning modules in practical mathematics for the technical-vocational track in terms of a) context of the students; b) online learning approach; c) roles of the online teacher; d) technology tools used; and e) presentation of the online learning modules; and

2. determined how the first iteration group and second iteration group differ in terms of student's evaluation of the effectiveness of the technology-mediated learning modules in practical mathematics.

Conceptual Framework

Figure 1

The conceptual framework of the study

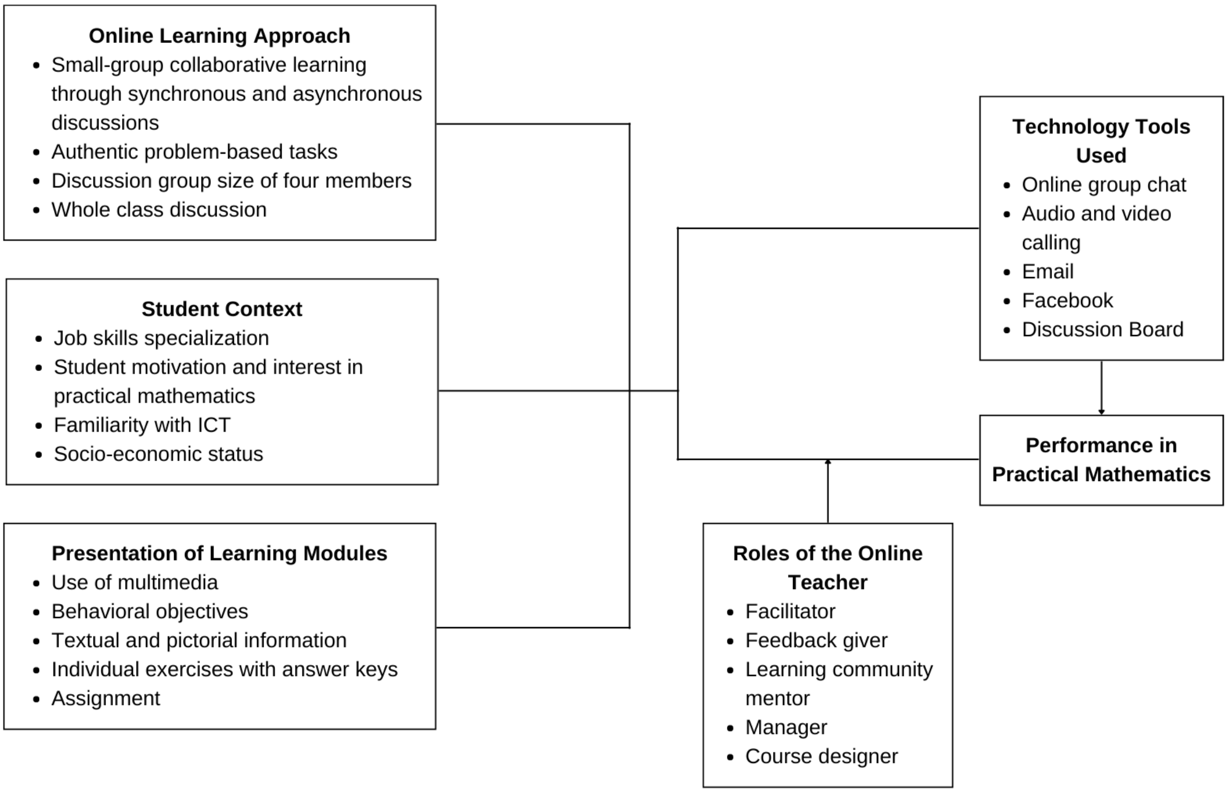


Figure 1 shows the conceptual framework of developing technology-mediated learning modules in practical mathematics using design research. The variables in the framework include the following: performance in practical mathematics, student context, online learning approach, roles of the online teacher, technology tools used, and presentation of the learning modules.

The student context is based on the personal characteristics and background of the student participants. These include the job skills specialization, motivation and interest in mathematics, familiarity with ICT, and economic status. The focus of the mathematics curriculum in technical vocational education should be the basic content of mathematics, not its higher content (Rose, 2012). Students who intend to specialize in welding and other technical vocational skills must master basic mathematics skills like the four fundamental operations, conversions of units, calculations on algebraic expressions, and computations of ratios and percentages. Student motivation and interest in mathematics are better addressed by online learning with problem-based tasks contextualized in real-world settings. These problem-based tasks with a variety of vocational contexts are embedded in UK vocational curriculum (Hodgen & Marks, 2013) and have been found useful for US vocational students with poor motivations to learn mathematics (ACTE Issue Brief, 2009). Students born in the 21st century have been described as digital natives, being raised in an environment surrounded by ICT (Prensky, 2005). Thus, the technical-vocational students of the 21st century are expected to be comfortable and familiar with the use of ICT tools like Internet-based tools. The challenge for these students, however, is the continued access to the Internet since many of them came from low-income groups (Foley, 2007). Hence, any online course in mathematics extended to these students should take into consideration their economic status.

The online learning approach is anchored on the social constructivism of Vygotsky (1978) that states that a learner constructs knowledge through the process of social interaction with others. Following Vygotsky's theory, learners of the study, as a whole class or small groups of size four, used collaborative learning through synchronous or asynchronous discussions. The whole class discussion was found to be a significant factor in students' interactions in online courses (Hewitt & Brett, 2017). Small group size enhances group work and discussion and is best conducive for collaborative learning (Du et al., 2007; Fernandez, 2007). To maximize interactions in a group, collaborative learning was organized around a problem-based task, which was contextualized in a real-world setting. This authentic task comes from real-world situations and promotes communication and collaborative learning (Jennings, 2006).

The zone of proximal development, Vygotsky's dominant construct, showed a zone in between what a learner can achieve independently and what he may achieve with scaffolding. Scaffolding may come from the teacher or the more experienced peers. The online teacher should thus, be a facilitator and a guide on the side rather than a sage on the stage. As a facilitator, the teacher should also assume other effective online teaching roles, including pedagogic, social, and managerial roles, as Berge (1995) proposed. Berge (1995) posited that the assumption of these roles would help an online teacher become a better guide of students, a good learning community mentor, a timely feedback giver, an effective manager, and a course designer.

The technology tools used in the study consist of a social network site and Internet-based tools. The educational platform of the study is a social network site that is good support for collaborative learning and serious deliberations (Gross, 2004; Mazman & Usluel, 2010). The asynchronous and synchronous classes utilize the Internet and Internet-based tools including e-mails, discussion boards, video and voice calling, video streaming, instant messaging (IM), and uploading and downloading functions.

The cognitive theory of multimedia learning (Mayer, 2001) and cognitive load theory (Sweller & Chandler, 1991) have been applied in the presentation of the learning modules. The first theory states that readers will understand the material better when words and pictures are presented compared to words only. In the latter theory, an extraneous load—how information is presented to the learners—may come in two forms: either in verbal or spatial form. Between the two forms, the spatial form reduces the extraneous load, thus enabling the limited cognitive resource to process the intrinsic load and germane load. Using the multimedia learning theory and cognitive load theory, the learning module of the conceptual framework does not only contain textual and pictorial information but also video information on the lesson of the day. The multimedia presentation of the lesson is very helpful in student construction of knowledge and in enhancing a constructivist learning environment (Neo & Neo, 2003).

A learning module in the framework of the study has a set of learning objectives, based on the cognitive domain of Bloom's Taxonomy. The domain caters to the acquisition of knowledge and the development of intellectual skills (Bloom et al., 1956). In this study, a set of learning objectives, in hierarchical order, serves as goals of the learning process, which learners must pursue and achieve after studying a learning module.

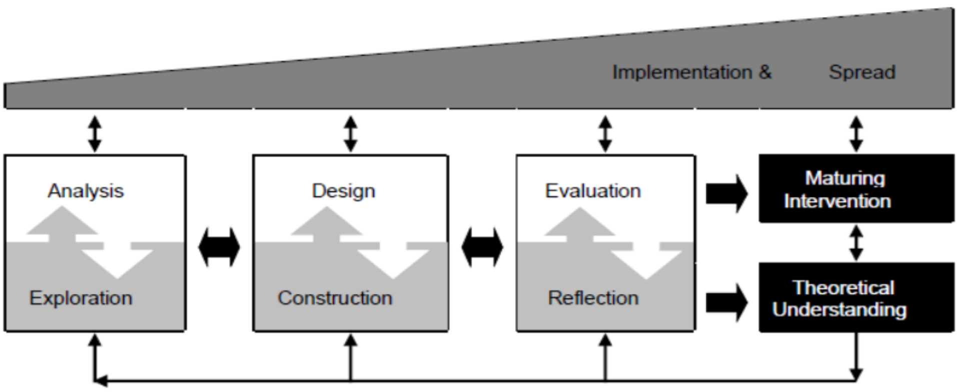
In this conceptual framework, the dependent variable is the test outcome in practical mathematics and the independent variables are student context, online learning approach, and presentation of the online learning modules. Student participants—who have mastered the skills and knowledge in basic mathematics, are exposed to the vocational contexts of their chosen specialization, are familiar with Internet-based tools, and are motivated to study mathematics—are likely to perform better in the practical mathematics test. With the use of the online learning approach and presentation of online learning modules, they are also expected to achieve the same student outcome. The mediator variable of the study is the use of technology tools of the study. In the absence of these technology tools, online learning in practical mathematics is not possible. The moderator variable of the study is the assumption of roles of the online teacher. How effective the assumption of these roles by the teacher will either weaken or strengthen the relationship between the independent variables and dependent variable of the study.

Methodology

Figure 2 shows the research design of the study that made use of Mckenney and Reeves's (2013) design research model. Based on this model, the research and development process of the study (see Figure 3) started with the analysis of the problem and a literature review on developing online modules. The outcome of the initial phase informed the tasks of the next phase: selection of design principles and construction of tentative online modules. These tentative modules were tried out in the two-iteration implementation of the study. Each iteration ended with evaluation and reflection which was the last phase for improvement or further improvement of the modules. The process culminated in producing two outputs: the theoretical output consisting of validated design principles and the practical output consisting of the improved online learning modules.

Figure 2

Design research model of Mckenney and Reeves (2013)



Participants of the Study

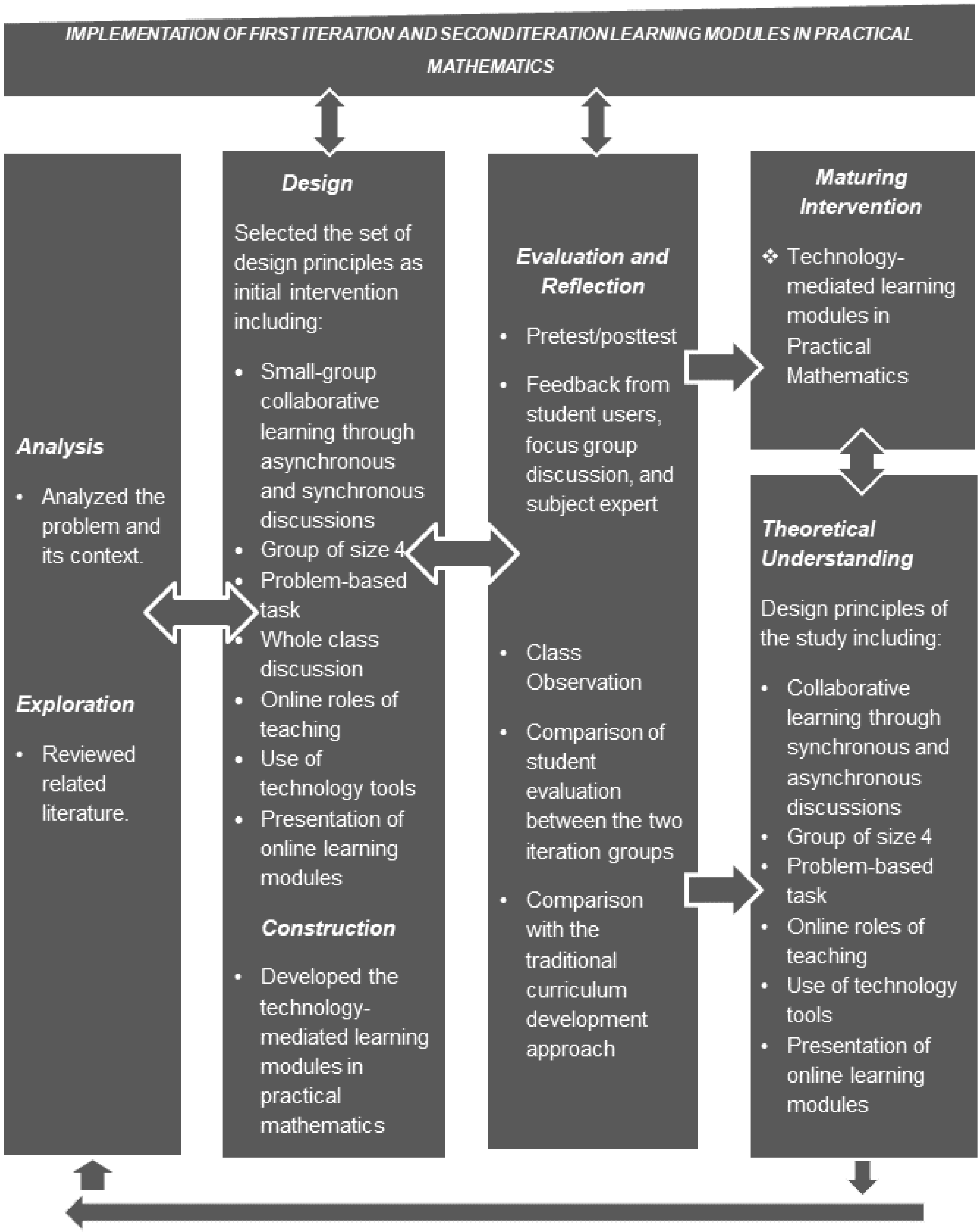
For the first iteration, the participants involved twelve Grade 11 students enrolled in the technical vocational institute and senior high school of a private sectarian college in Southern Philippines. In the second iteration, another twelve Grade 11 students, also enrolled at that private sectarian college in the pioneering technical-vocational track, joined the study to try out the three technology-mediated learning modules in practical mathematics, which were already modified based on the results of the first iteration.

Research Instruments

This study used three researcher-made instruments, namely, an evaluation rubric, an observation guide, and a semi-structured interview protocol. A panel of two subject experts was asked to examine and establish the content validity of these three instruments.

Figure 3

Research and development process of the study based on the research model of Mckenney and Reeves



Technology-Mediated Learning Modules in Mathematics

Using the design research approach, three (3) technology-mediated learning modules were developed based on the three (3) topics found in the training regulations for "Shielded Metal Arc Welding" (SMAW) NC II. These three topics, which include conversion of units, calculations on algebraic expressions, and computation of ratio and percentages, are particularly taken from the training regulations' common competency entitled, "Perform Industry Calculations". These topics cover seven (7) lessons. Each of these lessons has the following activities:

1. *Problem roll-out.* An online teacher, as a facilitator, would inform each small discussion group on what was expected of them in this activity. After reading the problem and its sub-questions, members of each group had to discuss among themselves what they knew about the problem, what they needed to know, and the potential next steps that they knew about.

2. *Student work time.* As the next activity, each small group would work on the potential next steps that they knew about. Here, an online teacher would ask some probing questions beginning with what, how, or why— leading the students to the right process or desired outcomes. A teacher could also remind them of prior knowledge, as stated after the lesson objectives, to be helpful in the analysis towards solving the sub-questions of a problem-based task.

3. *Workshop.* In this activity, an online teacher would announce that each small group could avail of a workshop should they come to the potential next steps of the problem that required what they needed to know. This entailed watching a video tutorial on what they needed to know about the problem. They could replay any portion of the video presentation as needed. To reinforce what they learned from the video tutorial, the group would be given a set of exercises to answer. Afterwards, an online teacher would direct the group to self-check their answers through the answer key as uploaded on the educational platform of the study.

4. *Sharing and discussion.* This next lesson activity would allow a volunteer group to present and discuss their output before the whole class. An online forum, facilitated by an online teacher, would follow. Groups, especially those struggling ones, could ask clarificatory questions; other groups could comment on the presentation of a group's output. Here, an online teacher could also comment or ask questions to ensure that what was presented to the whole class was accurate and clear for proper guidance of those groups who had difficulty performing the problem-based task of a lesson.

5. *Student work time.* The group could use this time to revise or completely write the solutions to the questions of the problem-based task. This activity could be capped by groups doing some extension work.

6. *Final action on the problem.* At this time, the groups would submit reports of their outputs that included solutions or mathematical justifications to the main question and sub-questions of the problem-based task. An online teacher would then score and comment on these submissions. Upon teacher's feedback, these corrected outputs would be returned to the groups for reflection on any errors committed or to keep them as part of the review materials. Also, the group would work on an assignment, an extension work but not a required submission, to reinforce what they have learned from a lesson.

Each lesson is composed of a video tutorial, helpful notes from a video tutorial, an answer key, and a solution key to an assignment.

Implementation of First and Second Iterations of the Design Process

In the first iteration implementation, 12 participants were divided into three (3) small discussion groups. Each group of four (4) members was provided with a Facebook group account. The participants tried out the first iteration of learning modules for seven weeks. In this online implementation, the researcher was the facilitator, and a high school mathematics teacher was the class observer who observed the researcher's facilitation as well as the small groups that tried out the learning modules. Of the 12 participants who joined the first iteration, eight (8) completed the study while four (4) dropped out. After completing the online study that lasted for seven weeks, these eight participants answered the evaluation rubric in order to rate the learning modules they tried out. Moreover, six (6) of these participants were interviewed by the researcher using the interview protocol. The gathered data from the participants, the class observer, and the researcher served as the feedback of the study. These feedbacks were used to improve the first iteration of the learning modules.

In the second iteration, another group of 12 participants used the modified learning modules. These participants were divided into three (3) small discussion groups. Assigned with a Facebook group account, each small group of four members tried out the modules for seven (7) weeks. The researcher facilitated these discussions and observed the groups that tried out the learning modules. Upon completion of the seven-week online study, all 12 participants answered the evaluation rubric, and five (5) of them were interviewed by the researcher. Feedback gathered from the participants and observer were analyzed and used for further refinement of the second iteration learning modules.

Data Analysis

This study used qualitative and quantitative techniques in analyzing the data gathered in this study. In both iterations of the study, descriptive statistics were generated to describe the evaluation of the learning modules by the students and the class observer. The four ratings in the evaluation rubric were described as excellent, good, fair, and needs improvement. From excellent to needs improvement, these ratings were coded as 4, 3, 2, and 1, respectively. Based on the data obtained from the evaluation rubric, this study used percentage scores to characterize the design principles of the study. Mean scores were computed to determine the overall student evaluation of the effectiveness and usability of the first and second iteration modules. To establish how well the technology-mediated modules facilitated the learning of the concepts in practical mathematics, the Mann-Whitney test was used to compare the mean scores from the evaluation rubric of the first and second iteration groups. Moreover, observation and interview data were analyzed as follows: a) coding of responses, b) validating the codes, c) identifying themes, and d) consolidating themes and information. The results of which were also used to characterize the design principles of the study.

Ethical Considerations

Research participants were informed about the purpose of the study and that their participation is voluntary and for educational use only. To ensure data privacy and confidentiality, no sensitive and personal information was gathered from the participants and their responses were treated with anonymity.

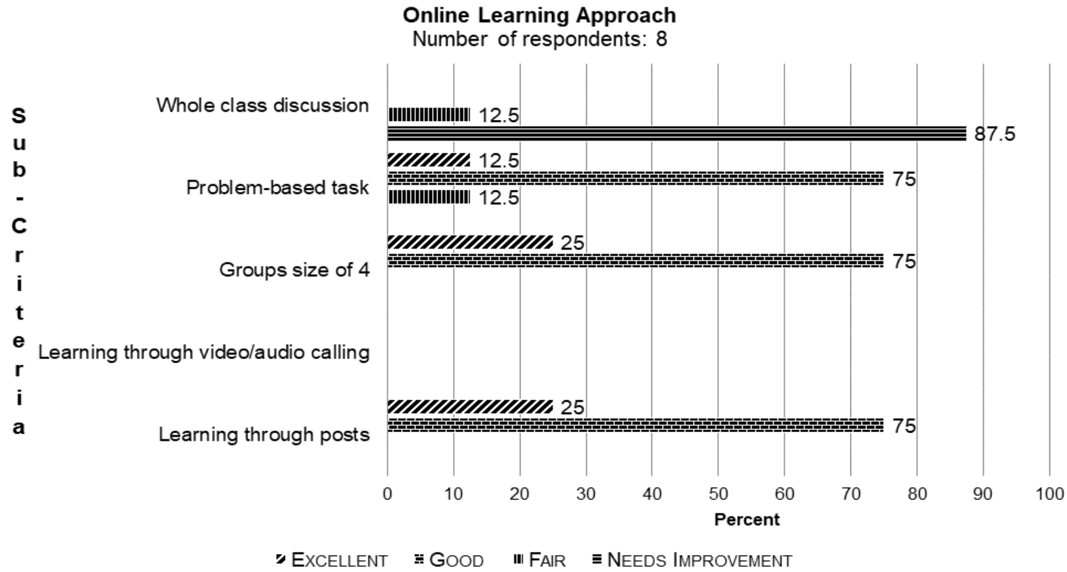
Results and Discussion

Characterizing the Technology-Mediated Learning Modules

Student Context. The majority of the first iteration participants were enrolled in a manual arc welding course. With a mean age of 17.1 years old, these participants, who are 21st century learners, were observed by the facilitator and class observer to be proficient in the use of Internet-based tools. The breadwinners of the participants' families were either laborers or tricycle drivers. The second iteration participants also shared the same context with the first iteration participants.

Figure 4

First iteration participants' perception of the online learning approach in practical mathematics



Online Learning Approach. Figure 4 shows the first iteration results of the design principles that constitute the learning approach of the study. Learning through video or audio calls, which was not possible at that time due to poor Internet connection, was excluded from being rated by the participants. Majority of the participants rated these design principles including learning through posts, having a group size of four, and answering problem-based tasks with good. This indicates that the participants were able to learn collaboratively as they can communicate their ideas well and understand and learn from other's ideas through posts. This was also observed by the researcher and the class observer as they found the participants to be learning well using the open chat in a synchronous manner. One theme from the interview of selected participants shows that they were able to discuss well with the other members of the group and that the exchange of ideas during the online discussion was good.

A good rating on the small discussion group indicates that at least three out of four participants are interacting and helping each other perform the lesson tasks during the iteration. This student perception on size of discussion group would favor the advocates of small group size who argued that the best collaborative learning takes place in a group of two to six students (Barkley et al., 2005). The student interviewees also found a small group size conducive to synchronous discussion, but the shared output on the discussion board and the ensuing whole class discussion were not useful. As also observed by the class observer and researcher, the presentation of the shared output on the discussion board did not generate a class-wide interaction. Each small group was more involved in their online group chat with the facilitator when they performed a problem-based task. In the succeeding learning modules, not one group asked for a presentation of the shared output on the discussion board. A good rating on the problem-based task indicates that the participants were 75% sure of their solutions and had enough time to perform the task and submit the output on or before the scheduled deadline. A theme from the interview responses was best expressed by one participant: “I find the problem-based task of a module not so difficult.” This was also the general observation of the class observer and researcher.

In general, improvements made on the first iteration modules in terms of the online learning approach include the following: a) encouraging asynchronous discussions on identified areas of problem-based tasks that require longer reflection; and b) introducing changes for better illustration and simplification of some problem-based tasks.

In the second iteration, another group of participants, who tried out the improved first iteration modules, rated the collaborative learning through posting of ideas on group chats as excellent. By also rating it as “good,” the second iteration participants affirmed the first iteration result of the size of the discussion group. When compared to the perception of the first iteration participants on the problem-based task, the perception of the second iteration participants has further improved with more than 50% of them rating the problem-based task as excellent.

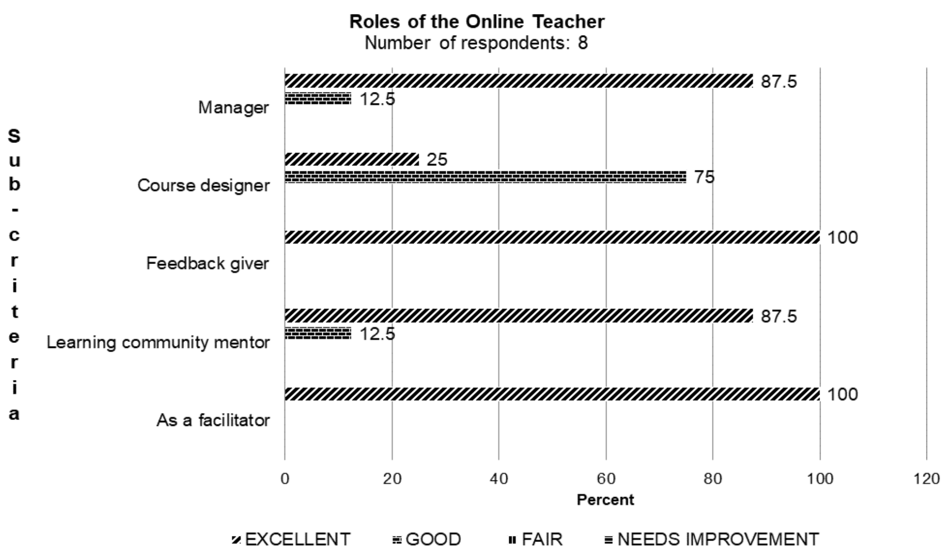
After the second iteration, as a further improvement on the online learning approach, more asynchronous discussions were integrated into some lessons, and the members of the discussion group were reduced to three.

Roles of the online teacher. Figure 5 shows the design principles for the roles of the online teacher. Except for the course designer role, all were rated excellent by the majority of the first iteration participants. Interview responses of participants on the assumed roles of facilitator and feedback giver were characterized by the following remarks:

a. “Our facilitator is always present in every discussion and guiding us in every task.
b. “Feedback was great.”

Figure 5

First iteration participants’ perception of roles of the online teacher in practical mathematics



When asked how they experienced the social presence of the online teacher as a learning community mentor, most of the interviewees stated that they felt such presence during group work and reported that the teacher knew them well. The class observer noted that this was evident in the self-introduction of the online teacher as well as the opportunity given to the participants to introduce themselves. As an excellent manager, the online teacher was perceived to have given a very satisfactory orientation on the house rules of online learning and to have provided satisfactory responses to all the participants' concerns and questions that affect online learning of this course. Such management tasks were also noted as evident by the class observer.

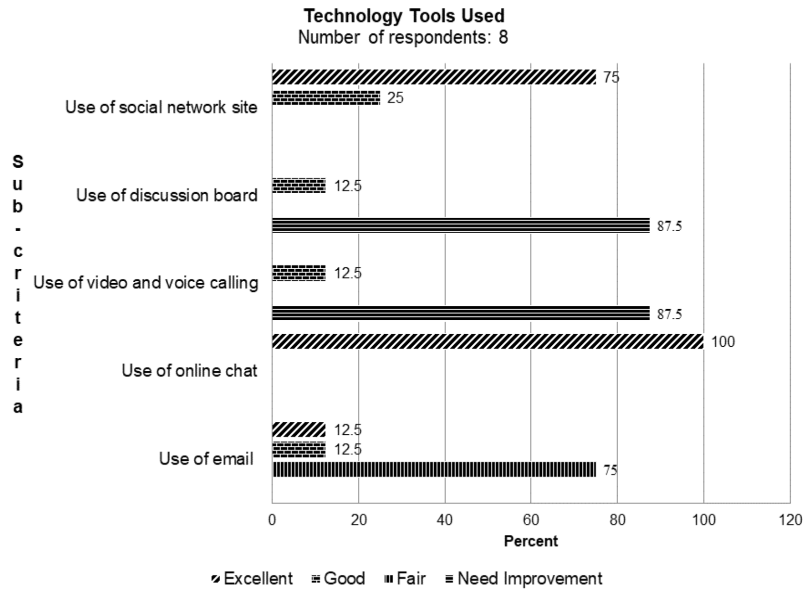
Majority, at 67 percent, perceived the online teacher to be a good course designer because they found the activities in all seven lessons were well-thought-out and well-organized. Upon closer examination of the technology-mediated learning modules, instructions were clear, and lesson objectives were also clear, measurable, and achievable.

No further improvement was made on the design principles for online teacher roles in the first iteration as these principles were maintained in the second iteration.

The second iteration participants rated all the assumed roles of online teaching, including course designing rated as good in the first iteration, as excellent. The themes that emerged from the interview responses of the second-iteration participants on the assumption of roles of online teaching were similar to the themes identified in the first iteration.

Figure 6

First iteration participants' perception of the technology tools used in learning practical mathematics



Technology tools used. Figure 6 shows all the first iteration participants perceived online chat as an excellent tool to communicate ideas about what they know and how to solve a lesson's problem-based task. The majority viewed Facebook as an excellent social network site for the study because it provided the most conducive platform for online learning of the modules. The participants, as observed by the class observer and the researcher, enjoyed the ease and convenience of using Facebook because the site provided them with tools like instant messaging and file sharing in discussing and performing a problem-based task at hand.

Most of the participants found video or voice calls for online learning as one area that needs improvement. Based on the interview of selected participants, they could not use these technology tools to discuss a lesson because of the connection issues encountered in the various Internet cafes they visited. Poor Internet connection was also highly evident during the observations of the researcher and class observer. It was further noted that the participants did not use the discussion board to see a shared output and discuss it class-wide. This was due to the participants' preference for a small group discussion guided by a facilitator over a class-wide discussion. Majority of the participants rated fair on the use of email, which indicates that it was the least used by the participants during the online study. This also emerged as a theme from the interview responses on the use of email by the participants. Although email can be a good tool for asynchronous discussion, many of its functionalities such as uploading and downloading, are also provided by Facebook, the groups' chosen social network site. Facebook has provided faster and more convenient services that include instant messaging, uploading and downloading files and pictures, and video and audio calling to the participants.

As an improvement on the first iteration modules in terms of technology tools used, the use of email, video and voice calls, and discussion board was removed. Thus, the second iteration participants utilized Facebook and its group chats as available tools for online learning, which they rated as excellent.

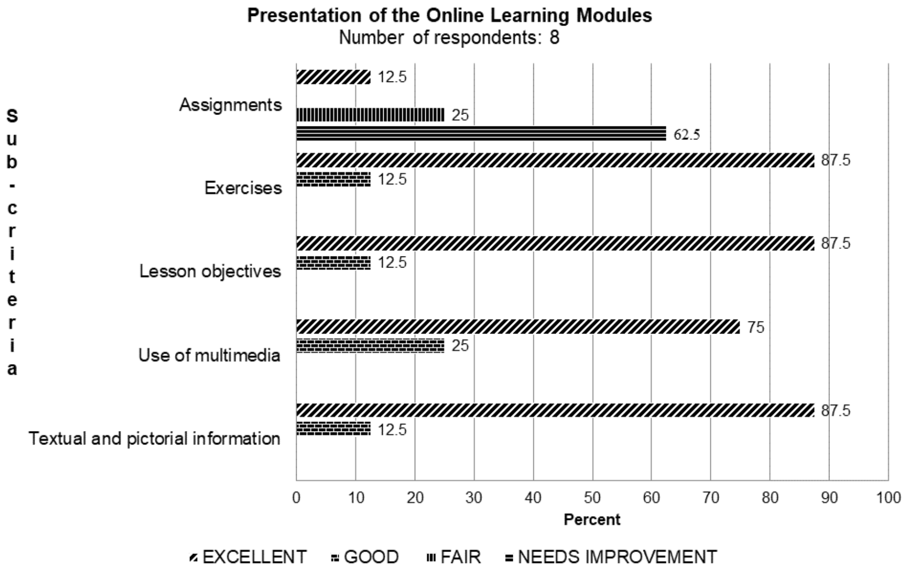
Presentation of online learning modules. Figure 7 shows that the majority of the first iteration participants rated the following design principles— textual and pictorial information, use of multimedia, lesson objectives, and exercises, as excellent. Themes from the interview responses of selected participants, which supported student perception included:

1. The video tutorials were "good, especially to those who lacked knowledge on the lesson," "clear and effective," and enhanced the social presence of the facilitator.
2. Helpful notes "provided a good concept so that we won't forget the important inputs coming from the video tutorials," and "helped us develop our skills and understanding of the lesson."
3. The textual information contained instructions and words which were clear and well-understood.
4. The pictures were highly motivating and interesting.
5. Lesson objectives were clear, measurable, and achievable in most modules.

Most of the participants found the assignment an unattractive task to work on after performing all the lesson activities, including problem-based task. Besides, an assignment in a lesson was not part of the required submission to the online teacher.

Figure 7

First iteration participants' perceptions of the presentation of technology-mediated learning modules in practical mathematics



As an improvement on the online learning modules, two lesson activities— sharing and discussion and making the assignments— were removed from the first iteration learning modules in practical mathematics.

In the second iteration, only half of the participants rated excellent on the use of multimedia, and textual and pictorial information. The slow Internet connection must have accounted for a decline in the proportions of participants who rated both design principles as excellent, from more than 50% in the first iteration to just 50% in the second iteration. For instance, when interviewed participants of the second iteration were asked about the tutorials in video format, some commented that the video tutorials helped them understand the lesson well, but others were unable to view the video tutorials because of their weak Internet connection. Thus, they had to rely on the notes provided to them to help them learn what they needed to know. On lesson objectives and individual exercises, 75% of the second iteration participants rated them as excellent; these perceptions were similar to those of the majority of the first iteration participants.

The themes that emerged from the coded responses of the second iteration interviewees were similar to those themes obtained in the first iteration.

Student Evaluation of the Learning Modules' Effectiveness

Table 1 shows the mean scores of the four clusters of the evaluation rubric for the first and second iterations. An overall mean score, which is the average of the scores on the 15 sub-criteria of the evaluation rubric, is computed for each of the two iterations.

Table 1

Mean Scores of Student Perceptions of the Technology-Mediated Learning Modules in Practical Mathematics by Cluster

Cluster	Mean Scores (First Iteration)	Descriptive Ratings	Mean Scores (Second Iteration)	Descriptive Ratings
Online learning approach	2.8	Good	3.3	Good
Roles of the online teacher	3.8	Excellent	3.9	Excellent
Technology tools used	2.8	Good	3.7	Excellent
Presentation of the online learning modules	3.3	Excellent	3.7	Excellent
Overall mean score	3.2	Good	3.7	Excellent
Number of respondents	8		12	

Using the Mann-Whitney test in Table 2, this study performed a two-tailed test to determine any significant difference in the mean scores of the evaluation rubric between the first iteration group and the second iteration group. Table 2 shows the test results at 0.05 significance level with $n1=8$ and $n2 = 12$. Since the computed U-value = 0 is less than the critical U = 22 at $p<0.05$, the null hypothesis is rejected in that the overall mean score of the second iteration group is significantly higher than the overall mean score of the first iteration group. This result shows a significant improvement of the overall student evaluation from a good rating of the first iteration modules to an excellent rating of the second iteration modules. This further indicates that the technology-mediated learning modules facilitated the learning of practical mathematics concepts.

Reconceptualized Framework

Several changes, consisting of a major one and other minor ones, were integrated in the reconceptualized framework (see Figure 8).

As the major difference between the two frameworks, the cluster of design principles for the presentation of learning modules has been reassigned from being an independent variable in the conceptual framework to a moderator variable in the reconceptualized framework.

As a minor difference between the two frameworks, one lesson activity in the conceptual framework —the assignment – was taken out from the cluster of present learning modules of the re-conceptualized framework.

Although the cluster of design principles for the online learning approach is maintained as an independent variable, some minor changes from this cluster, have been made part of the reconceptualized framework. These minor ones, further differentiating between the two frameworks, include: a) more emphasis on the use of asynchronous discussions; b) simplification of the authentic problem-based task; and c) reduction of discussion group size from four to three members.

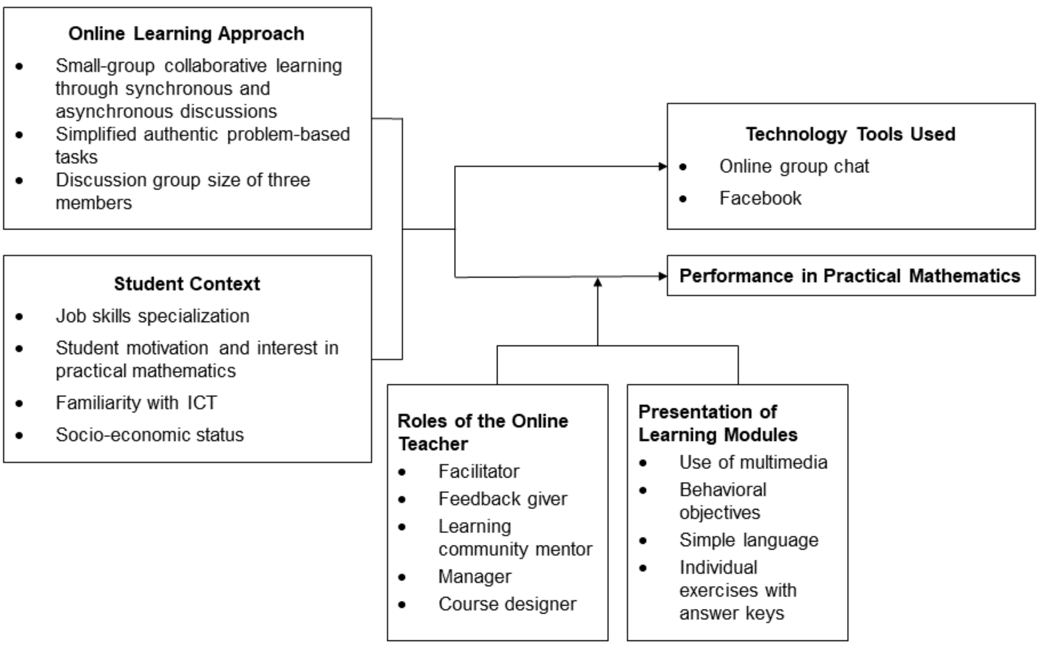
Student context is still maintained as an independent variable in the re-conceptualized framework. The personal characteristics and background of the first iteration group—in terms of job skills specialization, student motivation and interest in mathematics, familiarity with ICT, and socio-economic status—were similar to those of the second iteration group. There is, however, one exception that provides a distinction between the two frameworks. A student participant in the re-conceptualized framework has a greater interest in the study of practical mathematics than a student participant in the conceptual framework.

In terms of technology tools used in the study, its cluster of design principles is still maintained as the mediator variable, making possible the relationship between the two independent variables and the dependent variable of the study. In the re-conceptualized framework, some changes were introduced to the technology tools used to support the learning needs of the participants. These included the removal of emails and discussion boards from the cluster of design principles. Because of weak Internet connection, other synchronous tools like video and audio calls were not available for use in the study and had to be removed from the available tools in the reconceptualized framework.

Another cluster of design principles, roles of the online teacher has moderated the relationship between the online learning approach and test performance. As perceived by the participants, class observer, and researcher in both iterations, the excellent teaching roles facilitated the online learning process and thus strengthened such relationships.

Figure 8

The re-conceptualized framework of developing technology-mediated learning modules in practical mathematics using design research



Conclusions and Recommendations

Based on the findings of the study, the following conclusions are made:

1. The technology-mediated learning modules in practical mathematics, developed using the design research approach, have facilitated the learning of practical mathematics

concepts. A typical student participant, enrolled in a shielded manual arc welding course, is interested in studying practical mathematics and finds the mathematical tasks and level of difficulty of these modules manageable. The problem-based tasks with vocational contexts are relevant to his plan to find work after graduation from senior high school. The technology tools used like Facebook and open chat have well-supported the participants' preferred mode of learning—collaborative learning through synchronous or asynchronous discussions. The student participants communicate their ideas well in the open chat, track and understand others' posted ideas, and learn from others' posted ideas. The discussion group size of three is conducive for online collaboration as the size elicits active discussion from all the group members of the present study. The assumed roles of facilitating and giving feedback guide each small group discussion very well, keep the participants fully engaged on the problem-based tasks, and provide complete feedback on the exercises and group outputs.

2. The other assumed roles—learning community mentoring, course designing, and managing—highly satisfy the participants' learning needs and non-academic concerns, organize the activities of the modules, and create a community of learners among student participants. The multimedia presentation of the modules helps participants understand more deeply the lessons of the modules. Words used are simple and easy to understand while the set of exercises helps the participants master the practical mathematics concepts.

The findings of the study imply great importance in developing learning modules towards achieving the desired outcomes in an open and distance e-learning platform. Any such process may either contribute to or hinder achieving those desired goals. As shown in this study, the design research approach was found to approximate the best possible outcomes of online teaching and learning in practical mathematics. Thus, the following recommendations are made:

1. Course designers, who want to develop online learning modules for the mathematics curriculum of the technical vocational track of the K to 12 programs, should use design research approach because its iteration process, involving both students and teachers in developing the modules, yields a theoretical output for effective online teaching and learning of mathematics.

2. The design research modules of the study can be used for online learning and teaching on the seven lessons of practical mathematics because these modules proved to have facilitated the learning of practical mathematics concepts.

3. For further research, another design research study on developing technology-mediated learning modules in Geometry and Trigonometry may be conducted. Using the same design research process, future studies should consider the following:

   a. Increase the number of student participants;
   b. Provide the participants with continued access to a strong Internet connection; and
   c. Use a classroom-based comparison group.

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